THE REACTION OF SEEDLINGS OF *CITRUS* SPP. AND RELATED GENERA TO *PHYTOPHTHORA CITROPHTHORA*

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Synopsis

Varieties and selections of *Citrus* and related genera were inoculated with *Phytophthora citrophthora* to determine their resistance to root and collar rots.

Poncirus trifoliata and its hybrids, *Microcitrus australis* and *Severinia buxifolia*, were highly resistant to stem inoculations of *P. citrophthora* ; mandarins were intermediate in susceptibility, while Rangpur lime, sweet orange varieties, Smooth Seville and rough lemon were highly susceptible. Smooth Seville is moderately resistant to root rot. Ruby Blood 3118 and Parramatta orange 3443 were more resistant to Phytophthora root rot than other sweet orange selections tested.

Of 150 clones of *Poncirus trifoliata*, all were uniformly and highly resistant to Phytophthora root rot.

Introduction

Phytophthora citrophthora (Sm. and Sm.) Leon, which causes root and collar rots, is one of the most destructive pathogens of citrus in New South Wales. The use of resistant rootstocks offers an excellent means of reducing the losses from root rot, and the resistant rootstock *Poncirus trifoliata* (L.) Raf. is widely used in New South Wales. However, it grows poorly in highly acid, highly alkaline or saline soils and is unsuitable for use as a rootstock for Eureka lemons (*Citrus limon* (L.) Burm. f.) because of its susceptibility to exocortis virus (scalybutt), which many old-line lemons carry. There is also an incompatibility factor which causes a bud-union weakness (Nauriyal *et al.*, 1958) with " Eureka " lemons. Therefore, an alternative Phytophthora-resistant stock without these disadvantages is needed and has been sought over a number of years.

Field behaviour of citrus stock-scion combinations in root rot-liable soils is difficult to assess on the basis of laboratory, glasshouse or small field plot testing. Factors other than the intrinsic susceptibility of the rootstock to rotting of roots are involved. The reaction to *Phytophthora* spp. of the scion, the regenerative ability of the stock, the level and type of nutrition, and possibly other factors may modify this and the final assessment must be made on long-term field behaviour. However, initial screening can only be made on the basis of the amount of disease resulting from inoculation, and several methods have been employed to arrive at a satisfactory rating.

Two species of *Phytophthora* are capable of causing root and collar rots of citrus, *P. citrophthora* and *P. nicotianae* (B. de Haan) var. *parasitica* (Dast.) Waterh. Their relative importance is dictated by temperature, *P. citrophthora* being the prevalent species at lower temperatures and *P. nicotianae* var. *parasitica* at higher temperatures. In New South Wales *P. citrophthora* is the predominant species. *P. nicotianae* var. *parasitica* is only rarely seen, and is restricted to the warmer parts of the central and north coast.

The resistance of citrus species and varieties as reported from California, where both species of *Phytophthora* occur, and Florida and Queensland, where

P. nicotianae var. *parasitica* is the predominant species, follows the same general pattern for both fungi, with only minor variation. No variation in pathogenicity of different isolates has been reported for *P. citrophthora*, but in Florida it has been found that considerable variation in pathogenicity occurs in *P. nicotianae* var. *parasitica* (Grimm and Whidden, 1962).

Methods of testing for Phytophthora resistance vary. Klotz and Fawcett (1930), Fraser (1942) and Rossetti (1947) studied the resistance of a large number of species and varieties of *Citrus* and related genera to bark inoculation with *P. citrophthora*, and Klotz *et al.* (1958*a*) examined the resistance to *P. nicotianae* var. *parasitica* using bark inoculations. To assess the percentage decay of fibrous roots by *P. citrophthora* and *P. nicotianae* var. *parasitica*, Klotz *et al.* (1958*b*) immersed the root systems in aerated water cultures containing the fungus. Carpenter and Furr (1962) inoculated roots with *P. nicotianae* var. *parasitica* and then transferred the seedlings to incubation beds to determine their reaction to infection. Incorporation of inoculum in soil in which the test plants are established has been fairly widely used. The results of all these different approaches indicate that resistance occurs in *Poncirus trifoliata* and its hybrids and to a lesser extent in *Citrus aurantium* L. (sour oranges), and a range of susceptibility is shown by orange, mandarin, grapefruit, lemon and other clones.

General Methods

Three methods of assessing resistance were used in this study:

(*a*) Infestation of steam-air treated (140° F./30 min.) soil by adding corn-meal sand cultures of pathogenic isolates of *P. citrophthora.*

(*b*) Growth of plants in Hoagland's solution (Hoagland, 1919) to which cultures of *P. citrophthora* on lucerne (*Medicago sativa* L.) stems were added.

(*c*) Inoculation of wounded stems.

Table 1

Reaction of Citrus *spp. and Related Genera to* P. citrophthora *in Soil*

Common Name	Botanical Name	Number of Plants with Collar Rot: Above Ground	Soil Level	Below Ground	Mean Root Rot Rating	Number of Plants Killed
Trifoliate orange	*Poncirus trifoliata* (L.) Raf.	0	0	0	0·8	0
Rusk citrange	*P. trifoliata* × *C. sinensis*	0	0	0	0·8	0
Sampson tangelo	*C. paradisi* × *C. reticulata*	0	0	2	1·5	0
Thornton tangelo	*C. paradisi* × *C. reticulata*	1	0	1	1·5	0
Harvard sweet orange	*C. sinensis* (L.) Osbeck	1	1	3	1·9	2
Cleopatra mandarin	*C. lycopersicaeformis* Hort. ex Tan.	1	1	1	2·1	1
Sathgudi orange	*C. sinensis* (L.) Osbeck	0	2	2	2·1	1
Emperor mandarin	*C. reticulata* Blanco	1	0	1	2·2	0
Rough lemon (South Africa)	*C. jambhiri* Lush.	2	4	2	2·2	2
Kara mandarin	*C. reticulata* Blanco	1	2	1	2·3	0
Ellendale mandarin	*C. reticulata* Blanco	1	0	1	2·3	0
Rough lemon (N.S.W.)	*C. jambhiri* Lush.	3	5	3	2·5	1
Volkamer lemon	*C. volkameriana* Pasq.	4	5	8	2·5	1
Ruby blood sweet orange	*C. sinensis* (L.) Osbeck	1	1	2	2·7	1
Karna Khatta	*C. karna* Raf.	7	6	7	3·1	6

Citrus seeds were germinated in containers of steam-air treated soil (140° F./30 min.) When four to six inches tall, 10 seedlings of each variety were selected for uniformity and planted singly in one gallon containers, or in rows in large troughs of steam-air treated soil or transferred to aerated nutrient solution.

Experimental

(1) *Reaction of* Citrus *spp. and Related Genera to Root Inoculations with* P. citrophthora : *In Soil*

Experiment 1 : Citrus seedlings in one gallon containers were arranged randomly on the glasshouse bench. Ten replicates and 15 varieties were used. Ten gm. of inoculum was placed at a depth of 4 cm. in three holes around each plant. Inoculum consisted of a mixture of 12 isolates of *P. citrophthora* grown separately on corn-meal sand for six weeks. Eight of the 10 replicates were harvested after 11 weeks and the final two replicates 18 days later.

The root rot rating of each plant was assessed on a scale ranging from 0 (no observable injury) to 5 (most of root system rotted) and each rating represents the mean of 10 replicates. (Results are given in Table 1.)

The hypocotyl region of plants of Karna Khatta, rough lemon, sweet orange and Volkamer lemon was particularly susceptible to infection by *P. citrophthora* (Table 1). Often severe collar infection occurred with little root damage. Mandarins and tangelos were less severely infected by *P. citrophthora* than sweet orange or lemon. In the two replicates examined at 14 weeks, growth of roots had recommenced after a winter dormancy, and the pioneer roots which had been produced were not attacked by *P. citrophthora* even though a very high concentration of inoculum was present in the soil.

Experiment 2 : The reaction to *P. citrophthora* of 21 sweet orange and 14 sour orange clones and a number of other varieties was assessed. Seedlings were grown in one gallon containers and inoculated at 16 months with corn-meal sand culture of four isolates of *P. citrophthora*. Plants were examined after six months and a visual assessment made of root rot injury on a scale similar to that used in Experiment 1. (The results are given in Table 2.)

In Aerated Nutrient Solution

Experiment 1 : Seedlings 6 in. high were suspended in aerated Hoagland's solution so that only the roots were immersed. A pathogenic isolate of *P. citrophthora* obtained from diseased citrus roots and grown on sterilized stems of lucerne, where it had produced sporangia, was enclosed in cheese-cloth and suspended in the culture solution for 24 hr. One month after inoculation the seedlings were removed from the Hoagland's solution and placed in a 1% solution of 2,3–5-triphenyl tetrazolium chloride (Klotz and De Wolfe, 1965) for 24 hr. in the absence of light and assessed on the basis of stained as compared with unstained roots.

Poncirus trifoliata, Troyer citrange, Ruby blood sweet orange, sweet orange (Symons clone), Smooth Seville (Warnock clone), Israel sour orange and rough lemon, in that order, showed increasing susceptibility to root rot as shown by stained living tissue. The method of testing susceptibility to *Phytophthora* root rot in aerated nutrient solution was a severe one, giving rapid results which were uniform for any given variety or species of citrus.

(2) *The Reaction of* Citrus *spp. and Related Genera to Stem Inoculations with* P. citrophthora

Seedlings, 18 months old, grown in one gallon cans, were arranged randomly on benches in the glasshouse in 10 replications. In Experiment 1, the resistance

TABLE 2

Reaction of Citrus *spp., Varieties and Related Genera to* P. citrophthora

Common Name	Botanical Name	Mean Root Rot Rating
Highly resistant :		
Trifoliate orange 22*	*Poncirus trifoliata* (L.) Raf.	1
Resistant :		
Stuart Smooth Seville (10)†	*C. aurantium* L. ?	1·5
Roberts Smooth Seville (10)	,, ,, ,, ?	1·6
Appleby Smooth Seville	,, ,, ,, ?	1·6
Haddon Smooth Seville	,, ,, ,, ?	1·7
Moderately susceptible :		
Parramatta orange 3443	*C. sinensis* (L) Osbeck	2
Ruby blood orange 3118	,, ,, ,, ,,	2·1
Rough lemon, Terrigal No. 3 selection (10)	*C. jambhiri* Lush.	2·1
Rough lemon, Terrigal No. 1 selection (10)	,, ,, ,,	2·2
Warnock Smooth Seville	*C. aurantium* L. ?	2·2
Rough lemon, Terrigal No. 4 selection (10)	*C. jambhiri* Lush.	2·4
Ellendale mandarin	*C. reticulata* Blanco ?	2·5
Citrus " *zigardia* " (a sweet orange type)	Origin unknown	2·5
Emperor mandarin (10)	*C. reticulata* Blanco	2·6
Marchant rough sour orange (10)	*C. aurantium* L.	2·6
Sweet orange 1259	*C. sinensis* (L.) Osbeck	2·7
Haddon rough sour orange A (10)	*C. aurantium* L.	2·7
Haddon rough sour orange C (10)	,, ,, ,,	2·7
Haddon rough sour orange B (10)	,, ,, ,,	2·7
Rough lemon, Terrigal No. 2 selection (10)	*C. jambhiri* Lush.	2·7
St. Michael orange 3109 (10)	*C. sinensis* (L.) Osbeck	2·9
Susceptible :		
Narara rough lemon	*C. jambhiri* Lush.	3
Cleopatra mandarin (N.S.W.) (10)	*C. lycopersicaeformis* Hort. ex Tan.	3
Brazilian sour orange	*C. aurantium* L.	3·1
Sweet lime (10)	*C. limettioides* Tan.	3·2
Wilson navel-type sour orange	*C. aurantium* L.	3·3
Chaffey sweet orange	*C. sinensis* (L.) Osbeck	3·4
Somersby rough sour orange A	*C. aurantium* L.	3·5
Somersby rough sour orange B	,, ,, ,,	3·4
Israel sour orange	,, ,, ,,	3·5
Pineapple orange 3199	*C. sinensis* (L.) Osbeck	3·6
Parramatta orange 3187 (10)	,, ,, ,, ,,	3·6
Bittersweet orange	*C. aurantium* L.	3·7
Parramatta orange 3188	*C. sinensis* (L.) Osbeck	3·8
Homosassa orange 3104	,, ,, ,, ,,	3·8
Waikerie sweet orange 3185	,, ,, ,, ,,	3·9
Highly susceptible :		
White Siletta orange	*C. sinensis* (L.) Osbeck	4
Yuzu (10)	*C. junos* Sub. ex Tan.	4
Jaffa orange 3610 (10)	*C. sinensis* (L.) Osbeck	4
Mediterranean sweet orange	,, ,, ,, ,,	4
Cleopatra mandarin (ex Florida)	*C. lycopersicaeformis* Hort. ex Tan.	4·1
Campuda sweet orange 3613 (10)	*C. sinensis* (L.) Osbeck	4·1
Parramatta orange 3146	,, ,, ,, ,,	4·2
Mayo orange	,, ,, ,, ,,	4·3
Paterson orange 3449	,, ,, ,, ,,	4·4
Calamondin (10)	*C. madurensis* Loureire	4·6
Maltese blood orange	*C. sinensis* (L.) Osbeck	4·8
Seedling sweet orange (Parramatta type)	,, ,, ,, ,,	4·8
Joppa orange	,, ,, ,, ,,	4·8

* Accession number referring to parent trees at the Department of Agriculture Horticultural Research Station, Narara.

† Number of plants tested was 20 unless otherwise stated.

of seven varieties of mandarin, Ruby blood sweet orange and rough lemon were tested. In Experiment 2 two trifoliate orange clones, five trifoliate hybrids, nine sweet orange clones and nine miscellaneous citrus species were tested. Discs of bark (5 mm. diameter) were removed with a cork borer from the collar region of the stem 40 mm. above soil level, inoculum inserted, and the area bound with plastic budding tape. Inoculum consisted of discs 5 mm. diameter cut from a six-day-old agar culture of *P. citrophthora* newly isolated from diseased citrus roots. The wrappings were removed after three weeks in Experiment 1, and after 10 days in Experiment 2 and the lesion measured. One plant of each variety was treated similarly, but no inoculum was added.

The reaction of mandarin varieties to collar rot is given in Table 3. *Poncirus trifoliata* and its hybrids, *Microcitrus australis* and *Severinia buxifolia*, were all highly resistant to stem inoculations of *P. citrophthora* (Table 4). The mandarins were intermediate in susceptibility, while Rangpur lime, sweet orange varieties, Smooth Seville and rough lemon were highly susceptible. There were no significant differences between sweet orange varieties (overall mean $=2\cdot03$, S.E. $(n^1=76)=\pm0\cdot08$ on 67 degrees of freedom). Similarly, the two trifoliate selections did not differ significantly (overall mean $=0\cdot127$, S.E. $(n^1=11)=\pm0\cdot043$

TABLE 3

Reaction of Citrus *spp. and Related Genera to Stem Inoculation with* Phytophthora citrophthora

Common Name	Botanical Name	Length of Lesion in Cm. (Mean of 10 replicates)
Kara mandarin	*C. reticulata* Blanco	0·92
Scarlet mandarin	,, ,, ,,	1·18
Emperor mandarin	,, ,, ,,	1·28
Ellendale mandarin	*C. reticulata* ?	1·36
Dancy mandarin	*C. reticulata* Blanco	1·49
Rough lemon	*C. jambhiri* Lush.	1·55
Acid mandarin	*C. reticulata* Blanco	1·66
North Coast sour mandarin	,, ,, ,,	1·76
Ruby blood sweet orange	*C. sinensis* (L.) Osbeck	2·05

Standard deviation: 0·451 cm. or 30·9%.

Difference necessary for significance (5%) in comparison of means = 0·451 cm.

on nine degrees of freedom). One F_2 seedling of Yanco hybrid 3700 was highly susceptible to collar rot infection. There were highly significant differences between citranges, Yanco hybrid 3694 being more resistant and Yanco hybrid 3700 more susceptible to collar rot than the other citranges (S.E. mean $(n^1=10)=\pm0\cdot027$ on 52 degrees of freedom). The reactions of Scarlet and Cleopatra mandarins did not differ significantly (overall mean $(n^1=14)=1\cdot66$ with S.E. $\pm0\cdot122$ on 12 degrees of freedom).

(3) *Reaction of* P. trifoliata *Selections and Trifoliate "Orange" Hybrids to* P. citrophthora: *Root Inoculation of* P. trifoliata

Seed was obtained from trees at the Horticultural Research Station, Somersby, where a collection of 148 clones of *P. trifoliata* collected in N.S.W. and two introduced from U.S.A. are maintained.

Experiment 1: Ten seedlings 10 cm. tall of each of 48 clones of *P. trifoliata* and one clone of rough lemon were planted in troughs 3 ft. × 2 ft. × 6 in. containing steam-air treated (140° F./30 min.) soil. The soil had been inoculated with a mixed inoculum of five-week-old corn-meal sand cultures of 12 pathogenic isolates of *P. citrophthora*. Two months after planting, the plants were washed free of soil and the root damage assessed.

Despite the severity of the test, *P. trifoliata* seedlings showed little root injury. No infection of mature tissue occurred, but root tips were often infected or rotted away. Of the rough lemon seedlings, nine died within one month of transplanting into the infected soil and the one remaining plant was surviving with one lateral root, the taproot, having been rotted.

Experiment 2 : One clone of rough lemon and 129 clones of *P. trifoliata* were planted in one gallon containers of steam-air treated soil (140° F./30 min.), 10 seeds per container. Dormant seedlings were inoculated when 7 in. tall by adding to each tin 1 gm. of mixed corn-meal sand inoculum comprising 10 isolates of *P. citrophthora* which had grown for one month.

All *P. trifoliata* seedlings were highly resistant to *P. citrophthora* root rot. The rough lemon seedlings developed severe root rot.

TABLE 4

Reaction of Citrus *spp. and Related Genera to Stem Inoculation with* Phytophthora citrophthora

Common Name	Botanical Name	Length of Lesion in Cm. (Mean of 10)
Yanco hybrid 3694*	*Poncirus trifoliata* × *Citrus sinensis*. F_2 generation	0·05
Box orange 54–93–9	*Severinia buxifolia* (Poir.) Tenore	0·05
Trifoliate orange 111	*Poncirus trifoliata* (L.) Raf.	0·08
Australian wild lime	*Microcitrus australis* (Blanco) Swing.	0·09
Troyer citrange	*P. trifoliata* × *C. sinensis*	0·1
Box orange 54–91–11	*Severinia buxifolia* (Poir.) Tenore	0·11
Yanco hybrid 3698	*P. trifoliata* × *C. sinensis*. F_2 generation	0·14
Yanco hybrid 3693	,, ,, ,, ,, ,, ,,	0·18
Yanco hybrid 3697	,, ,, ,, ,, ,, ,,	0·18
Trifoliate orange 113	*Poncirus trifoliata* (L.) Raf.	0·2
Yanco hybrid 3700	*P. trifoliata* × *C. sinensis*. F_2 generation	0·42
Scarlet mandarin	*C. reticulata* Blanco	1·57
St. Michael sweet orange	*C. sinensis* (L.) Osbeck	1·59
Cleopatra mandarin (N.S.W.)	*C. lycopersicaeformis* Hort. ex Tan.	1·74
Rangpur lime 3234	*C. limonia* Osbeck	1·82
Cummins sweet orange	*C. sinensis* (L.) Osbeck	1·93
Ruby blood sweet orange 3699	,, ,, ,, ,,	1·96
Viticultural nursery sweet orange	,, ,, ,, ,,	1·99
Maltese blood sweet orange 3206	,, ,, ,, ,,	2·07
Moorland sweet orange	,, ,, ,, ,,	2·08
Ruby blood sweet orange 3696	,, ,, ,, ,,	2·1
Ruby blood sweet orange 3695	,, ,, ,, ,,	2·2
Harrison sweet orange	,, ,, ,, ,,	2·54
Rough lemon	*C. jambhiri* Lush.	2·68
Smooth Seville 3151	*C. aurantium* L. ?	2·75

* Refers to the accession number of the tree from which the seeds were obtained at the Horticultural Research Stations at Narara and Somersby.

Experiment 3 : Seeds of Troyer citrange, rough lemon and 13 clones of *P. trifoliata* were planted in rows (20 seeds per row) in troughs 3 ft. × 2 ft. × 6 in. deep containing steam-air treated (140° F./30 min.) soil. When the seedlings were 4 in. high corn-meal sand inoculum of 12 isolates of *P. citrophthora* grown for one month was incorporated into the soil. After five months plants were washed free of adhering soil and the root damage was assessed.

Only eight of 40 rough lemon seedlings survived. The remainder had callused lesions in the collar region or on the taproot. In the majority of plants at least 50% of the root system had been destroyed and plants were surviving on two or three lateral roots as the taproot had been rotted. Root regeneration was a major factor in the survival of these plants. The trifoliate clones and Troyer citrange plants were all highly resistant to *P. citrophthora*. Some root tips had been attacked, but the disease had not spread to mature tissue.

Stem and Root Inoculations of P. trifoliata *Hybrids*

One hundred and nineteen F1 hybrids of Smooth Seville *P. trifoliata*, 130 F1 hybrids of Ellendale mandarin × *P. trifoliata* and 10 rough lemon plants of nursery row size were subjected to root and stem inoculation as described in Sections (1) and (2).

Stem inoculations did not produce collar rot lesions in hybrid plants, although the rough lemon seedlings developed collar rot. Two hybrids of Smooth Seville × *P. trifoliata* were highly susceptible to root rot, while the remainder were moderately resistant. Ellendale mandarin hybrids varied in their reaction. In most plants only the tips of feeder roots were rotted away, but in seven plants the percentage of roots rotted varied from 10 to 40, compared with rough lemon, where 50–70% of roots were rotted.

Discussion

The resistance of *Poncirus trifoliata* and the citranges to root and collar inoculation with *P. citrophthora* confirmed field and nursery observations. All clones of *P. trifoliata* tested, one of which was a tetraploid, were extremely resistant to Phytophthora root rot. This was in contrast to the variation found by Klotz *et al.* (1958*a*) in percentage decay of fibrous roots of trifoliate orange selections caused by *P. citrophthora* and by *P. nicotianae* var. *parasitica*. Carpenter and Furr (1962) also found the percentage survival of trifoliate orange selections to be highly variable following inoculation with *P. nicotianae* var. *parasitica* and postulated that the reaction of *P. trifoliata* and its hybrids to *P. nicotianae* var. *parasitica* may be related to the degree of dormancy. No evidence to support this hypothesis was obtained with *P. citrophthora* in trials in New South Wales. Furr, Carpenter and Hewitt (1963) considered that differences in susceptibility of trifoliate oranges may be due to differences between young and old root systems, as well as to differences in pathogenicity of the species and isolates of *Phytophthora*. This explanation cannot be applied to the behaviour of *P. citrophthora* in New South Wales, where it has been found that the immature tissue in the region of elongation of trifoliate orange roots is rotted but mature cells are not attacked (Broadbent, 1969).

It is possible that the Australian clones of *P. trifoliata* have been derived from a small number of original introductions, which might explain the narrow range of variation.

The New South Wales selection of rough lemon, Volkamer lemon and the South African selection of rough lemon showed similar susceptibilities to root and collar infections by *P. citrophthora*. These stocks are vigorous and adaptable, and suitable for lemons, but lack the resistance to root rot necessary for citrus replant situations. The Terrigal selections of rough lemon were slightly less susceptible to Phytophthora root rot than the commonly grown rough lemon selection, and further search within the species for a more resistant clone may be desirable.

The tangelos and mandarins showed intermediate resistance to *P. citrophthora* and were more resistant than most of the sweet orange selections tested. The Ellendale mandarin, an Australian variety which is postulated to be a natural tangor (Swingle and Reece, 1967), is unsatisfactory as a stock as all its seedlings are gametic.

Cleopatra mandarin is in limited use as a rootstock in Australia and overseas, and for mandarins has an advantage over rough lemon stocks. The rating of Emperor mandarin as slightly more resistant than rough lemon confirms field observations that seedling trees of this variety persist better in root rot situations.

The resistance to root rot caused by *P. citrophthora* of four selections of Smooth Sevilles is in agreement with field observations and with the results obtained by Grimm and Garnsey (1969) using *P. nicotianae* var. *parasitica*. Under certain conditions Smooth Seville is highly susceptible to collar rot caused by *P. citrophthora*. The taxonomic status of the variety here called Smooth Seville is in doubt. It is not typical sour orange as described (Hodgson, 1967). A relatively high percentage of bifoliate and gametic seedlings is produced. Differences in susceptibility of unifoliate and bifoliate seedlings have been noted by Grimm and Garnsey (1969). Smooth Seville performs reasonably as a stock for lemons, but is unsatisfactory for oranges as this stock-scion combination declines due to tristeza virus (Stubbs, 1963).

A high degree of susceptibility was shown by most sweet oranges. Sweet orange is commonly used as a rootstock on the neutral to alkaline, free draining sandy loam soils of the inland districts of New South Wales. Ruby blood selection 3118 and Parramatta orange selection 3443 were somewhat more resistant to Phytophthora root rot than most of the other sweet orange selections. It may be significant that the parent tree of the Parramatta strain of sweet orange was a 100-year-old seedling tree from Northmead (New South Wales). It was in this area, once a prosperous citrus growing district, that *P. citrophthora* caused serious damage in 1860 (Fraser, 1949).

The reaction to Phytophthora root and collar rots of the range of species and varieties tested has provided a measure of the relative resistance of seedlings of many varieties of *Citrus* spp. and related genera. This can be used as a basis for further testing in the field as rootstocks and also provide information on resistance for future breeding purposes.

The genetic constitution of the citrus host rootstock and the suitability of the environment are of prime importance in determining the course of development of Phytophthora root or collar rots in the field. In genera such as *Poncirus*, *Microcitrus* and *Severinia*, resistance is conferred by some factor of genetic constitution. Where resistance is not complete, the degree of damage caused can be influenced by age, chemical composition, succulence and vigour of the infected tissue (Carpenter and Furr, 1962).

Under field conditions, environmental factors can influence both the course of the disease and the host. Soil characteristics, soil temperature, soil oxygen and moisture levels influence the development of citrus root rot (Klotz *et al.*, 1965; Stolzy *et al.*, 1965*a*). A low supply of oxygen in soils prevents root growth and regeneration, creating an unfavourable soil condition for infected plants to overcome the adverse effects of root decay (Stolzy *et al.*, 1965*b*). Soil fertility, with its effect on tree vigour and root development (Fraser, 1949), and the effect of the scion on rootstock (Klotz *et al.*, 1967) are also important.

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